Combining Contexts and Ontologies: A Case Study and a Conceptual Proposal

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Abstract. Recently, approaches that combine contexts and ontologies taking advantages of their strengths have been developed. Each of them solves different problems from different perspectives. The objective of this paper is to present problems that are not solved up to date as well as to introduce a conceptual proposal. To this aim, we base our analysis on a collaborative B2B scenario that is relevant for todays competitive and highly dynamic environment.

1 INTRODUCTION

Today, there is an increasing interest on combining context and ontology to define information semantics. The effort for combining both approaches could be classified according to the objectives to be achieved in works focused on: modelling and knowledge representation [1], [2]; and achieving interoperable systems that require data from multiple information sources [3], [4]. In the first case, an ontology alignment that consists on defining different kinds of relations between the involved ontologies, is enough to achieve semantic interoperability. In the other, however, it is crucial to define an ontology mapping that consists on defining equivalence relations [5].

Particularly, our research is focused on achieving semantic interoperability between heterogeneous information systems to support a collaborative business-to-business (B2B) relation between trading partners. In this area, the main approaches are focused on the idea of similar ontologies. However, each enterprise has its own information systems, and the challenge here is how to semantically integrate these heterogeneous systems.

The objective of this paper is to present problems that are not solved up to now and introduce a conceptual proposal for combining context and ontology. To this aim, the paper is organized as follows: Section 2 presents related works. Section 3 presents a context definition. Section 4 presents a case study based on a collaborative B2B scenario, and discusses problems that arise when combining contexts and ontologies. Section 5 presents conclusions and future work.

2 RELATED WORKS AND DISCUSSION

It is possible to find formal and informal approaches defining an ontology [5], and a context [6], [7], [8]. Ontologies define a common understanding of specific terms, and thus make it possible the semantic interoperability between systems, but they can only be used after reaching consensus about their content. Contexts encode not shared individual interpretation schemas, that are easy to define and maintain since they can be created with a limited consensus among parties, but the communication between systems can be achieved only by constructing explicit mappings [4].

Therefore, taking into account that the strengths of ontologies are the weaknesses of contexts and vice versa, a number of approaches were developed which propose to combine both concepts to achieve information semantic interoperability. Following, we analyze two of them that are recent and improve others previously defined in the area.

2.1 A centralized approach

In [3], the ECOIN (Extended COntext INterchange) semantic interoperability framework has been defined. It proposes to define a single ontology consisting of generic terms without specifying their exact semantics and it specializes them in local contexts to express specific meanings. ECOIN defines mappings structuring lifting axioms [7] as a conversion function network, defining them for each modification dimension according to a context model. ECOIN results in a simpler context model, which works very well in a domain where it is possible to define a single ontology and to relate it with multiple contexts.

2.2 A decentralized approach

In [4], an extension of the OWL language, C-OWL, has been defined to represent contextual ontologies where a context is a concrete domain viewed from the description logic perspective. In this work, ontology is contextualized when its contents are kept local and mapped with the contents of other ontologies via explicit mappings using bridge rules. These rules represent the relations: *equivalent to, more general than, less general than, compatible and incompatible.* C-OWL allows a user to define ontologies alignment where it is inappropriate to define a global shared ontology. However, the limited expressiveness of the C-OWL fails to address the contextual differences found in most practical settings, as it will be shown later.

3 OUR VIEW OF CONTEXT

When we talk about context, intuitively, we think in the set of facts in which something exits or occurs. This idea is not reflected by approaches described in Section 2. Our intention is to apply the theory about context [7], [8], for information semantics modelling and combine it with ontology. In our opinion this is a more appropriate way to take advantage of both approaches strengths in complex domains.

In the theory defined in [7] and [8], axioms and statements p are only true in a context c. This fact is expressed by the formula

$$c' : ist(c; p)$$

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The context *c* is formalized as a first class object. Formulas *ist(c,p)* are always considered as themselves asserted within a context, *c'*. Although this formulas define a infinite regress, to manipulate context we have to define a limit.

In information semantics modelling area we could state that a context is a set of facts in which a concept interpretation is true.

$$c = \{a\ set\ of\ facts\} \quad and \quad p = concept\ interpretation$$

c and *p* could be an ontology or an ontology element.

Defining contexts as a set of facts instead of a label allows us to manipulate them in a flexible way as will be shown next.

About contexts relations, there are two proposed ways: lifting axioms and bridge rules [12]. The main difference between them is that lifting axioms are stated in an external context, which must be expressive enough to represent facts of all involved contexts, whereas bridge rules allow stating relations between contexts without the need of an external one. In Section 4.3, advantages of having an external context are analyzed. So, a relation *R* between context will be

$$c' : (ist(c_1; p_1) \quad \xrightarrow{R} \quad ist(c_2; p_2))$$

4 A CASE STUDY

Nowadays, enterprises work together with their trading partners to improve supply chain (SC) management. Then, there is a semantic heterogeneity that could be solved by using ontologies, but it is not enough. Two concepts can be differently related to each other in different contexts, as different enterprises. In a collaborative relation, it is primordial that each enterprise preserves its identity, particularly the semantic identity. So, it is necessary to make the context explicit.

From a business point of view, to allow a decentralized management, the *PartnertoPartner Collaborative Model* has been defined in [10], which proposes a peer-to-peer collaboration between trading partners. In this model, decisions are independently made with the aim of preserving the privacy and autonomy of each enterprise. Let us define an example where a brewery has collaborative relations with two of its clients: a retailer and a warehouse; each relation constitutes a different context, C_{RBR} and C_{RBW} respectively.

The management of each collaborative relation implies coordinating: private processes (PP) that are executed by each enterprise; and collaborative processes (CP) that are jointly executed by trading partners. CP are defined as abstract ones; and in order to implement it each trading partner has to define a business interface process (IP). This IP is responsible for the invocation and execution of those PP required for carrying it out. To allow the CP execution, Electronic Business Documents (EBDs) are exchanged between trading partners. EBDs are standardized data structures that replace traditional business documents [11].

When the IP receives an EBD, it has to translate it information to the PP according to the semantic of corresponding enterprise sector. Then, to send an EBD, the IP populates it with data of corresponding enterprise sector according to the CP semantics. So, to make interoperable systems, the IP has to solve a number of conflictive situations at semantic level considering that it is necessary to define equivalence relations between concepts. Next, some of them are analyzed from the theories defined in the previous sections considering the relation between the brewery and a retailer.

4.1 Multiple ontologies and multiple domains

In a collaborative relation, each EBD is described by an ontology [11] that is not a global or general one, but only an ontology that describes the EBD information semantics, which was agreed by both partners. The EBDs will be processed by partners' private processes that may involve different enterprise sectors. Even two sectors within the same enterprise for apparently similar applications have different views, resulting in similar but still not the same ontology. Then, it is clear that each enterprise has its own ontologies to describe the semantics of its systems and internal areas.

Figure 1.b shows a part of an ontology (O_{EBD}) shared by both trading partners that describes the semantics of EBD interchanged to agree on a replenishment plan. Even if both supplier and client could have multiple ontologies to describe their information semantics, in this paper and for simplicity purposes, we focus on one ontology for each enterprise, O_S and O_C respectively, Figure 1.a and 1.c.

Although the centralized integration proposal (Section 2.1) introduces a simpler ontological model, it is difficult and sometimes even impossible to implement this proposal in a collaborative B2B relation. That is because each enterprise in a SC has its own interests; and its information systems and data structures have been designed to achieve those interests. So, when these enterprises decide to join themselves in a collaborative process, they do it with a common interest but keeping their individuality and privacy. As regards context, the ECOIN definition is not applicable either, since a context is more than just possible instance values in a collaborative B2B scenario.

The decentralized proposal (Section 2.2), seems to be more appropriate to model this scenario, since it handles different ontologies. However, the manipulation of contexts lacks of needed expressively to represent that within the context C_{RBR} exists subcontexts such as Supplier, C_S; Collaborative Process, C_{CP}; and Client, C_C. This fact can be modelled with the theory of context described in Section 3 as:

$$C_{RBR} \quad : \quad ist(C_S, p_S)$$

$$C_{RBR} \quad : \quad ist(C_{CP}, p_{EBD})$$

$$C_{RBR} \quad : \quad ist(C_C, p_C)$$

where p_S, p_{EBD}, and p_C are truth propositions in their contexts.

4.2 Contexts within an ontology

Considering the *Type* term of the O_{EBD} ontology (Figure 1.b), it is associated to the *Packaging* and *Product* terms. Even though *Type* has the same semantics, since it describes the class or nature of the concepts it is associated to, the possible values it may take are different. In the case of *Packaging*, *Type* can be *Can* or *Bottle*. But, for *Product*, *Type* can be *Local* or *NKH*. This presents an ambiguity problem that could be solved by replacing the term *Type* by *PackagingType* and *ProductType*. In this way, however, terms are unnecessarily added to the ontology, and this practice could lead to a size increase [8]. In our opinion, a better solution is to consider *Product* and *Packaging* as different contexts inside of which the term *Type* is interpreted,

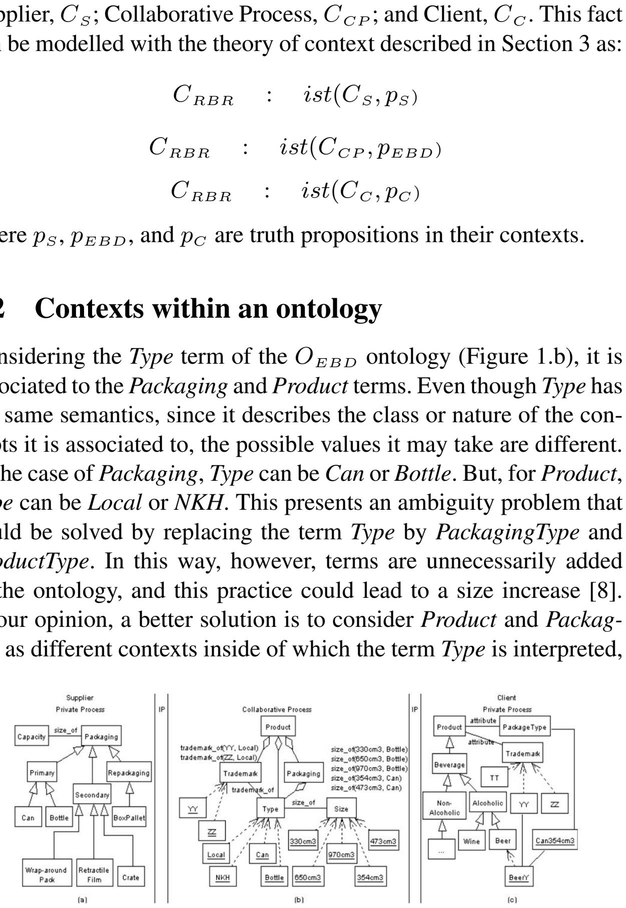

Figure 1. (a) Portion of one of the O_S ontology. (b) Portion of the O_{EBD} ontology. (c) Portion of one of the O_C ontology

defining them by a set of formulas like one shown in Table 1. In this table, *Product* and *Packaging* refer to O_{EBD} terms, and they are not simple labels, which give name to the contexts.

Table 1. Definitions of *ProductCxt* and *PackagingCxt* contexts

ProductCxt context	PackagingCxt context
ist(Product, part_of(Product, Type))	ist(Packaging, part_of(Packaging, Type))
ist(Product, Type(Local))	ist(Packaging, Type(Can))
ist(Product, Type(NKH))...	ist(Packaging, Type(Bottle))...

Here, different contexts are created within an ontology with the aim of solving name ambiguities [8]. This problem has no been tackled in the literature related to information system interoperability.

4.3 Relating contexts

Figure 1.c shows a client ontology portion, O_C. If the term *Trademark* is considered, it is an attribute of *Product* in O_C. This means, it is an attribute of all products and not just of beer. By contrast, *Trademark* $\in O_{EBD}$ (Figure 1.b) has a *part_of* relation with *Product*. Furthermore, *Trademark* $\in O_{EBD}$ has an association with *Type*, which is valid in the context *ProductCxt* but not on the context *PackagingCxt*. This relation does not exist in O_C because this information is irrelevant for the client. In spite of these differences, however, we can say that *Trademark* $\in O_{EBD}$ is equivalent to *Trademark* $\in O_C$ since their instances are equivalent to the collaborative context. These terms could be related by using equivalence mapping rules [4]:

$$O_{EBD} : Trademark \quad \xrightarrow{\equiv} \quad O_C : Trademark \quad \wedge$$

$$O_C : Trademark \quad \xrightarrow{\equiv} \quad O_{EBD} : Trademark$$

Considering this example, mapping rules defined in [4] are useful in cases where simple equivalence relations are enough to express similarities between contexts.

However, if previous rules are analyzed from the client context C_C point of view, these relations are not truth. The term *Trademark* of O_C is more general than the term *Trademark* of O_{EBD}, since it represents the trademark of all products and not only beers. That is:

$$O_{EBD} : Trademark \quad \xrightarrow{\subseteq} \quad O_C : Trademark$$

Previous rules, defined in this way, could carry incompatibility problems. A possible solution should be to contextualize them:

$$ist(C_{CP}, (O_{EBD} : Trademark \quad \xrightarrow{\equiv} \quad O_C : Trademark))$$

$$ist(C_C, (O_{EBD} : Trademark \quad \xrightarrow{\subseteq} \quad O_C : Trademark))$$

It is necessary to clarify that this is not a formalization, but only a way to express the idea that the rules linking terms belonging to different concepts also should be contextualized.

4.4 Different contexts, different representations

By comparing O_C and O_{EBD} (Figure 1.b - 1.c), the concept represented by *PackageType* in O_C is equivalent to *Size* and *Type* terms in O_{EBD}, for *Type* in the *PackagingCxt* context, but not in the *ProductCxt* context. So, *PackageType* $\in O_C$ is related to *Packaging*, *Type* and *Size* $\in O_{EBD}$ plus their relations. Analyzing the instances, *PackagingType(Can354cm3)* has to be translated into O_{EBD} as:

$$\begin{aligned} O_{EBD} \quad : \quad & ist(Packaging, (Type(Can)) \wedge \\ & ist(Packaging, Size(354cm3)) \wedge \\ & ist(Packaging, size\_of(354cm3, Can)) \wedge \\ & ist(Packaging, part\_of(Type(Can), Packaging)) \end{aligned}$$

That means that a certain concept is represented by a term in a particular ontology, but is represented as a set of terms, a set of relations and a context in another ontology. This example shows that in order to define mappings between different contexts it is necessary to define conversion rules that are more complex than mapping rules defined by [4] and the conversion function defined by [3].

5 CONCLUSIONS AND FUTURE WORK

The main contribution of this paper is a conceptual proposal that combines contexts and ontologies in order to manipulate semantic differences in a complex domain, such as a collaborative B2B scenario. This proposal is based on a previously defined context theory, however, we have explored the possibility to combine it with ontology concepts. Our approach proposes to define contexts as a set of facts that allow us to manipulate it in a more flexible way.

In a complex domain, having an external context may be an advantage. So, an interesting option to be analyzed is the definition of lifting axioms to define conversion rules between contexts. This analysis will be the focus of our future work, however, in this paper we have made progress in this sense. An important feature of these conversion rules is they have to allow us to relate a term in an ontology with a set of terms, a set of relations and a context in another.

The present proposal is incomplete and tentative since this is just the first step and further research remains to be done.

REFERENCES

[1] A. Segev, and A. Gal, *Putting Things in Context: a Topological Approach to Mapping Contexts and Ontologies*, 9–16, Contexts and Ontologies: Theory, Practice and Applications, AAAI Press, 2005.

[2] P. De Leenheer, and A. de Moor, *Context-driven Disambiguation in Ontology Elicitation*, 17–24, Contexts and Ontologies: Theory, Practice and Applications, AAAI Press, 2005.

[3] A. Firat, S. Madnick, and F. Manola, *Multi-dimensional Ontology Views via Contexts in the ECOIN Semantic Interoperability Framework*, 1–8, Contexts and Ontologies: Theory, Practice and Applications, AAAI Press, 2005.

[4] P. Bouquet, F. Giunchiglia, F. van Harmelen, L. Serafini, and H. Stuckenschmidt, 'Contextualizing Ontologies', *Web Semantics: Science, Services and Agents on the World Wide Web*, **1**: 4, 321–419, (2004).

[5] A. Gómez-Pérez, M. Fernández-López, and O. Corcho, *Ontological Engineering*, Springer Verlag, London, 2nd edn., 2004.

[6] P. Brzillon, 'Context in problem solving: A survey', *The Knowledge Engineering Review*, **14**: 1, 47–80, (1999).

[7] R. Guha, *Contexts: A Formalization and Some Applications*. PhD Thesis. Computer Science Dep., Standford University, 1995.

[8] J. McCarthy, and S. Buvac, *Formalizing Context* (Expanded Notes), Computer Natural Language, 1997.

[9] M. Theodorakis, *Contextualization: An Abstraction Mechanism for Information Modeling*. PhD Thesis. University of Crete, Greece, 2001.

[10] P. Villarreal, M. Caliusco, M. Galli, E. Salomone, and O. Chiotti, *Decentralized Process Management for Inter-Enterprise Collaboration*, 69–79, Vision, Special Issue on Supply Chain Mgment, **7**, India, 2003.

[11] M.L. Caliusco, M. R. Galli, and O. Chiotti, 'Ontology and XML-based Specifications for Collaborative B2B Relationships', *CLEI Electronic Journal*, **7**: 1, (2004).

[12] P. Bouquet, and L. Serafini, *On the difference between bridge rules and lifting axioms*, 80–93, Proc. 4th CONTEXT, LNCS 2680, 2003.